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The differential effect of background music on memory for verbal and visuospatial information

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ABSTRACT

Background music is a part of our everyday activities. Considerable evidence suggests that listening to music while performing cognitive tasks may negatively influence performance. However, other studies have shown that it can benefit memory when the music played during the encoding of information is also provided during the retrieval of that information, in the so-called *context dependent memory effect*. Since controversial results may be attributed to the nature of the material to be memorized, the aim of the present study is to compare the potential effect of consistent background music on the immediate and long-term recall of verbal and visuospatial information. Experiment 1 showed that instrumental background music does not benefit nor decrease recall of a list of unrelated words, both at the immediate and the 48-hours-delayed tests. By contrast, Experiment 2 revealed that the same background music can impair immediate and therefore long-term memory for visuospatial information. Results are interpreted in terms of competition for neurocognitive resources, with tasks mostly relying on the same brain hemisphere competing for a limited set of resources. Hence, background music might impair visuospatial memory to a greater extent than verbal memory, in the context of limited capacity cognitive system. In conclusion, the nature of the material to be learnt must be considered to fully understand the effect of background music on memory.

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Introduction

Nowadays, background music is constantly present in our everyday lives. We hear it in the supermarket, in the car, in elevators or at home, but there are certain circumstances in which background music can be more beneficial than others. Although music has been proven to have a positive effect on emotion and motoric behavior, it also seems to have a detrimental

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effect on cognitive performance and particularly on memory (Kämpfe, Sedlmeier, & Renkewitz, 2011). Background music has been considered a distractor for complex mental work (Smith, 1961), especially in tasks that require a conscious effort such as reading (Treisman, 2006). Indeed, there is evidence suggesting that background music, as well as background speech and other irrelevant noises, can disrupt short-term verbal and spatial retention by competing for processing resources (Röer, Bell, & Buchner, 2014b, 2014a, Salamé & Baddeley, 1987, 1989; Schlittmeier, Hellbrück, & Klatte, 2008; Tremblay, Parmentier, Hodgetts, Hughes, & Jones, 2012). However, there is some evidence that suggests the opposite. Smith (1961) showed that background music could benefit memory by what he called *context-dependent memory*. It occurs when traces of the environmental context are encoded along with information that is being memorized (Grant et al., 1998). When the same context is provided during retrieval, it will act as a memory cue and increase memory recall (Abernethy, 1940; Grant et al., 1998; Smith, 1979). Hence, factors influencing whether background music might have a detrimental or beneficial effect in the learning of new material warrant further research. The present study considers whether stimulus modality (verbal vs visuospatial) interacts with background music modulating memory performance.

As previously discussed, most authors seem to conclude that background music impairs mental work. However, many authors found positive results for memory performance when the music that was played at the encoding and retrieval phase remained the same (Isarida, Kubota, Nakajima, & Isarida, 2017; Mead & Ball, 2007), in accordance with the context-dependent memory effect. But there are still some inconsistent findings. For example, Balch, Bowman, & Möhler (1992) found that background music was not beneficial in long-term recall (48 h between the immediate recall and long term recall), even though it did have positive results in immediate memory.

A source of variability that may account for contradictory results in these studies had to do with the type of music. Felix (1993) reviewed studies that tested whether background music affects learning. The reported studies varied on the type of music presented to the participants and the tasks to be performed (paired-associate learning being one of them). Felix concluded that music played during learning affects performance positively, especially when the music played concerned baroque and classical pieces. Other studies using background music at both encoding and retrieval determined that relaxing music was more helpful when performing cognitive tasks (Cassidy & MacDonald, 2007). Indeed, the mood state induced by the tempo of background music seems to serve as a memory cue that improves listeners' performance (Balch & Lewis, 1996), in accordance with Eich's theory of

Mood Dependent Memory (Eich, 1980, 1995). Isarida et al. (2017), however conducted a similar experiment in which they found an effect of background dependent memory but no mood mediation. Nevertheless, mood state seems to be not the only factor involved in this memory process. In his *Mental Context Hypothesis*, Smith (1995) argues that the context is actually composed by a number of factors (e.g. mood state, place, etc.) that are processed as a whole, which we refer to as context. So when all these factors are presented together, they work as a cue for what was memorized in that context.

But, to fully understand the effect of background music on the performance of a memory task, the neurocognitive aspects of simultaneously processing music and memory material, and the possible kind of interference processes involved, should be considered. Most studies exploring the effect of context on memory use verbal material for the memory task, such as lists of words (Hockley, 2008; Smith & Manzano, 2010), an article whose content had to be memorized (Grant et al., 1998), or a test for college students (Saufley, Otaka, & Bavaresco, 1985). It is known that the vast majority of people have left hemispheric dominance for language processing (Frith, Friston, Liddle, & Frackowiak, 1991; Knecht et al., 2000; Vigneau et al., 2006), especially right-handed people. The right hemisphere, however, is dominant for processing of visual-spatial relations (e.g. Benton & Tranel, 1993; Corballis, 2003). Evidence also suggests that music processing seems to preferentially rely on the right hemisphere, especially for people with no formal musical training (Bever & Chiarello, 1974; Ono et al., 2011; Santosa, Hong, & Hong, 2014), although some elements, such as tone processing or the ability to read and analyze music, seems to be more related to the left hemisphere (Gordon, 1983).

Simultaneous performance of two tasks that are preferentially processed by the same hemisphere may negatively affect the performance of at least one of them (Kinsbourne & Hiscock, 1983). Indeed, this effect has been previously reported in an experiment in which participants had to complete a tactual maze using either the left or the right hand while listening to music played in either one ear or another. Performance improved when the music was in the ear contralateral to the hand used, particularly when the music was played in the left ear and the maze was completed with the right hand. More interesting, binaural music facilitated maze learning when the right hand was used, by reducing interhemispheric competition from the right hemisphere (McFarland & Kennison, 1988).

Whether the kind of material to learn can explain part of the variability of results on the beneficial effect of using background music as context during memory tasks is still an open question. In particular, the differential effect of musical context on the encoding and retrieval of verbal and visuospatial material has not been studied to date. Consequently, in this study we explored, through two interrelated experiments, whether instrumental background music differentially interacts with verbal (Experiment 1) or visuospatial information (Experiment 2), leading to a differential memory performance in those tasks. We expect that recall of verbal material will benefit from background music contextual effects, in the absence of intrahemispheric competition, while visual recall will decrease when music is presented on both encoding and recall phases, probably as a result of intrahemispheric competition for resources in a limited capacity system.

Experiment 1

The first experiment explored the effect of background music on memory for verbal material. Since processing of instrumental music preferentially relies on the right hemisphere, it should not significantly compete for neurocognitive resources at the encoding and recall of verbal memories. Moreover, and according to *context-dependent memory* evidence, music should act as a memory cue and enhance subsequent recall.

Method

Participants

The sample consisted of 60 volunteers (15 men and 45 women), non-musicians, between 18 and 35 years old, and with no records of psychological or neurological disorders. None of them reported auditory problems. All the participants completed an ad-hoc questionnaire, which included questions about age, years of musical training, if they studied using background music, and the Edinburg Handedness Inventory (Oldfield, 1971), as reported in Table 1. All these participants scored lower than 23 on the Edinburgh Handedness Inventory, since volunteers with higher scores were considered left-handed, and therefore were initially discarded. Participants in the sample were randomly assigned to one of two

Table 1. Participant's demographic information in experiment 1 and 2.

	Background music	Silence
Experiment 1: Verbal input		
Age	22.47 (4.23)	23.80 (5.24)
Years of musical training	0.97 (2.51)	1.13 (3.06)
Edinburgh Handedness Scale	18.27 (3.25)	18.23 (3.04)
Experiment 2: Visuospatial input		
Age	23.27 (5.53)	21.60 (3.07)
Years of musical training	1.17 (2.77)	1.47 (2.90)
Edinburgh Handedness Scale	16.63 (3.30)	18.87 (2.78)

Standard deviations are shown in parenthesis.

groups: Background music group ($n = 30$) and Silence group ($n = 30$). An independent sample T-test was conducted to confirm that that both groups were equivalent in age [$t(58) = 1.08$, $p = .28$].

Material

The verbal material consisted of a list of 16 words from Algarabel's (1996) database. This database provides a series of psycholinguistic indexes for 1917 Spanish words. Word frequency was on a scale ranging from 1 to 941, while subjective indices such as pleasantness, imageability, and concreteness were rated on a scale of 1 to 7 (1 lowest and 7 highest). Requirements for the words to be included in the study were: a standard length (mean amount of letters = 5,50; *sd* = 1,03; range from 4 to 8), medium level of pleasantness (mean = 3,52; *sd* = 0,39; range from 2,94 to 4,08), medium frequency of use (mean = 35,19; *sd* = 5,96; range from 27 to 45). Also, standard imageability (mean = 3,76; *sd* = 0,92; range from 2,28 to 6,17) and medium level of concreteness (mean = 4,08; *sd* = 1,14; range from 2,28 to 6,31). Words had no semantic or phonological relationship. A fragment of the Piano Concert No. 24 on C minor from Mozart was used as musical background. The first 2 min were selected and constantly repeated, so that participants were exposed to a consistent context. The volume remained the same for all participants.

Design

The experiment consisted of two sessions. During the first session, the list of unrelated words was visually displayed on a laptop screen, at a rate of 4 s per word, with an interstimulus interval of 2 s. Participants were told to pay attention to all words and try to learn them. Following the encoding phase, all participants answered a short questionnaire with demographic questions and the Edinburgh Handedness Scale (Oldfield, 1971), which can be administered in 3–5 min. Then, an immediate free-recall test followed. During the second session of the experiment, which took place 48 h later, participants came back to the laboratory for a delayed free-recall test. In both recall tests, participants were provided with a blank piece of paper and instructed to write down all the words they remembered. No derivative of the words or phonological differences were admitted as correct responses.

Participants in the Background music group listened to the above-described musical piece through a set of circumaural headphones (Sennheiser HD201, Sennheiser Electronic Corporation, USA) during the encoding, the immediate recall and the 48 h delayed recall. Background music started 10 s before the presentation of the first item of the list.

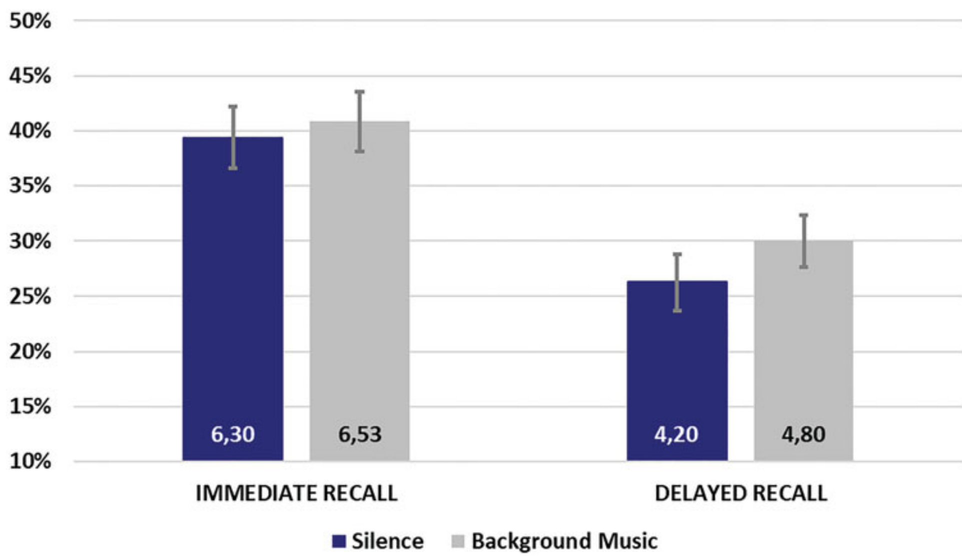

Figure 1. Percentage of correct recalled words at the immediate and the long-term recall of Experiment 1. Mean direct scores (out of a total of 16 to-be-remembered words) are shown at the bottom of the corresponding bar. Error bars represent standard error of the mean.

Participants in the Silence group performed all sessions and stages in silence.

Results

A mixed between-within subjects ANOVA was computed to explore the effect of the background music on participants' immediate and delayed recall of the list of words previously encoded. Results, as illustrated in Figure 1, showed a significant main effect of moment of recall [Wilks' Lambda = .42, $F(1,58) = 77.68$, $p < .0001$, partial eta squared = .57], with lower performance at the delayed recall than at the immediate recall. Neither the main effect of background music [$F(1,58) = .57$, $p = .45$, partial eta squared = .01] nor the interaction effect [$F(1,58) = .71$, $p = .40$, partial eta squared = .01] were significant.

Discussion

As expected, participants in the experiment remembered more words at the immediate recall than on the delayed recall, regardless of the background music. Although the delayed recall is probably determined by performance at the immediate test, this result suggests that the memory trace weakened from the encoding to the 48 h-time recall (Ebbinghaus, 1880; Jonides et al., 2008; Murre & Dros, 2015).

Our results show that background music does not benefit nor decrease recall, both at the immediate and delayed tests. Some authors have argued that background music can induce mood states that may themselves serve as contextual cues to improve memory (Balch & Lewis, 1996; Eich, 1980, 1995). However, it is possible that our design failed at inducing a particular mood state. The time of exposure to the context, i.e. the background music, was determined by the rate of presentation of the complete list of words, which last for 1 min and 36 s. This time might not be enough to generate a mood state robust enough to serve as a contextual cue (Eich, 1980, 1995). Moreover, Smith's (1995) *mental context hypothesis,* considers mood an important factor that contributes to generate mental contexts. Therefore, it seems reasonable that the mental context created through the present design was not strong enough to modulate recall.

On the other hand, some authors have argued that background music may act as a distraction for mental work and particularly for memory (Kämpfe et al., 2011; Konečni, 1982; Treisman, 2006). Although background music in this experiment did not benefit memory, participants who learned with background music did not obtain lower results either. Background music in our design consisted of a classical piece with no lyrics, while memory items were unrelated words. According to some authors, instrumental music does not include a distracting element for phonological information that could compete for neurocognitive resources, thus leaving room for processing verbal information (Jäncke, Brügger, Brummer, Scherrer, & Alahmadi, 2014).

These issues considered altogether may account for the absence of background music effects at immediate or long-term memory recall for verbal material consisting on unrelated word lists. A short exposure to background music would have limited the formation of a context strong enough to serve as a memory cue. At the same time, the absence of significant competition for neurocognitive resources, given the differential contribution of right and left hemispheres in the processing of background music and verbal material, may have prevented background music to impair memory for the list of words. If this had been the case, the same experimental design, but using visuospatial material, should yield different results in terms of the effect of background music on recall. Visuospatial processing relies strongly on the right hemisphere and might be more influenced by background music than verbal processing. This was the focus of Experiment 2.

Experiment 2

In the second experiment, the experimental design remained the same, but the list of items to be learnt and recalled was modified. Research back in the 90s had shifted to a more moderate view on the differential processing of each hemisphere (Martinez et al., 1997; Mehta & Newcombe, 1991). However, later evidence has rekindled the classical belief by reporting right hemisphere advantages in tasks that require visuospatial processing (e.g. Corballis, 2003; Ng et al., 2000). Thus, unlike in Experiment 1, where unrelated words were used, a series of geometrical figures were presented to participants in this experiment. Considering that the right hemisphere is engaged in the processing of instrumental music and visuospatial patterns to a greater extent than the left hemisphere, participants who learned and recalled while listening to background music should experience greater competition for neurocognitive resources and therefore lower recall scores than those in the group who perform the test in silence.

Method

Participants

The sample consisted of 60 volunteers (15 men and 45 women), non-musicians, between 18 and 35 years old, and with no records of psychological, neurological, or auditory disorders. All the participants completed the ad-hoc questionnaire described in Experiment 1, and results are reported in Table 1. As in Experiment 1, all participants scored lower than 23 on the Edinburgh Handedness Inventory, since volunteers with higher scores were initially discarded. The final sample consisted of 60 right-handed participants who were randomly assigned to one of two groups: Background music group ($n = 30$) and Silence group ($n = 30$). As in Experiment 1, results from independent sample T-test confirmed that both groups of participants were equivalent in age [t $(58) = -1.44$, $p = .15$].

Material

The visual material consisted of a list of 7 geometrical figures selected from the Visual Reproduction test from Wechsler Memory Scale III (Wechsler, 1997). The same musical piece, consisting of a fragment of the Piano Concert No. 24 on C minor from Mozart, was provided as background music in the corresponding group of participants.

Design

As in Experiment 1, the procedure consisted of two sessions. During the first session, the list of 7 geometrical figures was visually displayed on a laptop screen, at a rate of 10 s per figure, with an inter-stimulus interval of 2 s. Participants were instructed to pay attention to each figure and try to learn them. After completing the short demographic questionnaire and the Edinburgh Handedness Scale (Oldfield, 1971), they all underwent an immediate free-recall test. Forty-eight hours later, participants came back to the laboratory to perform a delayed free-recall test. In both recall tests, participants were provided with a blank piece of paper and instructed to draw all the figures they remembered. Criteria from the WMS-III correction manual was followed to consider responses as correct. Each image on the Visual Reproduction scale in the WMS III is scored by points. The simplest figure is scored with a total of 3 points, and it reaches a total of 7 points for the more complex figures. To consider each participant's response correct, they had to have a full score in all the criteria given by the WMS III. If this was the case, each correct image counted as 1 and as, mentioned earlier, there were 7 images in total. According to the design in Experiment 1, participants in the Background music group listened to the above described musical piece through a set of circumaural headphones (Sennheiser HD201, Sennheiser Electronic Corporation, USA) during the encoding, the immediate recall, the 48 h delayed recall and the recognition stage. Background music started 10 s before the presentation of the first item of the list. Participants in the Silence group performed all sessions and stages in silence.

Results

Results from a mixed between-within subjects ANOVA (background music x recall), as illustrated in Figure 2, revealed a significant main effect of moment of recall [Wilks' Lambda = .69, $F(1,58) = 25.76$, $p < .0001$, partial eta squared = .30], with lower performance at the delayed recall than at the immediate recall. More interesting, the main effect of background music was also significant [$F(1,58) = 9.94$, $p < .005$, partial eta squared = .14], with the Background music group performing worse than the Silence group. The interaction effect was not significant [$F(1,58) = .92$, $p = .34$, partial eta squared = .01].

Discussion

In accordance with Experiment 1, participants in this experiment also remembered more geometrical figures at the immediate recall than on the delayed recall, regardless of the background music, suggesting that visuo-spatial memories are also vulnerable to forgetting (Wang & Thomas, 1992).

Besides, background music does not seem to benefit recall of geometrical figures. Since the purpose for the current experiment was to assess the effect of competition for neurocognitive resources between background

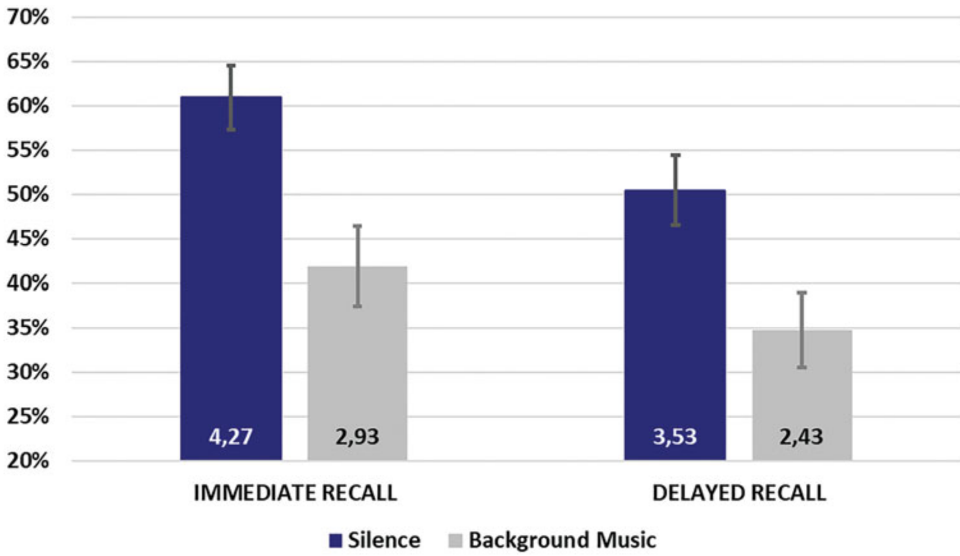

Figure 2. Percentage of correct recalled geometrical figures at the immediate and the long-term recall of Experiment 2. Mean direct scores (out of a total of 7 to-be-remembered figures) are shown at the bottom of the corresponding bar. Error bars represent standard error of the mean.

music and visuospatial material, the experimental set was maintained as close as possible to that of Experiment 1, with the exception of the learned and recalled material. As in Experiment 1, the time of exposure to musical context was brief, hindering the generation of a strong context that could act as a cue to improve recall (Eich, 1980, 1995; Smith, 1995). In this experiment, however, a significant difference between the Background music group and the Silence group did appear. Participants who completed the task with background music performed poorly at the immediate and the delayed recall, when compared with the volunteers who complete the memory task in silence. These results suggest that background music might exert a significant detrimental influence for visuospatial learning.

In non-musicians, as participants in these experiments, music tends to engage to a higher extent right hemisphere resources (Bever & Chiarello, 1974; Ono et al., 2011; Santosa et al., 2014). Similarly, visuospatial processing has historically been linked to the right hemisphere (e.g. Benton, 1969; Benton & Tranel, 1993). Although subsequent research has tempered this statement (Martinez et al., 1997; Mehta & Newcombe, 1991), more recent research has retaken the view of the right-hemisphere dominance for visuospatial processing (e.g. Corballis, 2003; Ng et al., 2000).

Because music and visuospatial information are preferentially processed by the right hemisphere, simultaneously processing background music and geometrical figures seemed to have disrupted learning and retrieval of the latter. Long-term recall was also worse in the Background music group than in the Silence group. However, the absence of a significant interaction between background music and moment-of-recall ruled out an effect of background music on visuospatial memory consolidation. Instead, the lower performance of participants who gave the 48 h delayed recall while listening to background music seems to reflect an extension of the effect at the immediate recall. In other words, if participants in this group remember fewer items at the immediate recall, it is predictable that they will remember fewer in the long-term recall, when compared with those in the Silence group.

General discusion and conclusion

Background music is nowadays constantly present in our daily activities. However, whether listening to music while accomplishing other tasks results is beneficial or not has been under debate for decades. A meta-analysis on this matter has revealed a large variability of results that are mainly explained by factors such as the style of background music, the type of concurrent task or the mood state experienced by the listener (Kämpfe et al., 2011). The present study focused on the effect of background music, when provided as a consistent context, on short- and long-term memory for verbal and visuospatial information. Particularly, a major aim was to test whether part of the variability of results on the effect of background music on memory could be attributed to competition for neurocognitive resources between music and verbal or visuospatial material, as suggested by previous work in motor cognition (McFarland & Kennison, 1988).

In accordance with this conception, background music hindered the immediate recall of geometrical figures, but not of unrelated words, presumably as a result of the higher competition for neurocognitive resources between music and visuospatial processing. Research back in the 90 s had shifted to a more moderate view on the differential processing of each hemisphere (Martinez et al., 1997; Mehta & Newcombe, 1991). However, later evidence based on neuroimaging and lesional approaches support the conception of left hemisphere dominance for verbal material and right hemisphere control in the processing of visuospatial information (e.g. Corballis, 2003; Ng et al., 2000), particularly in right-handed individuals. Similarly, instrumental music processed as one and not divided into different elements, seems to be mainly right-lateralized (Bever & Chiarello, 1974; Ono et al., 2011; Santosa et al., 2014). Therefore, simultaneous engagement in both listening to music and memorizing visuoespatial material may induce competition for resources in a limited capacity system (Jansen, Flöel, Menke, Kanowski, & Knecht, 2005) and result in poor performance in the memory task (McFarland & Kennison, 1988).

Nevertheless, there is another factor that may explain the difference in performance between visuospatial and verbal memory tasks. Recent research has proposed that the limited capacity of the cognitive system as a whole may explain the detrimental effect of memory performance while simultaneously listening to background music (Lehmann & Seufert, 2017). In other words, listening to background music could deteriorate memory performance because of competition for resources, regardless of the type of music and material in the memory task. Therefore, result in Experiment 2 could be due to the visuospatial task being more difficult than the recall of words. This would be a plausible and simpler alternative interpretation to the one based on intra-hemispheric competition. However, a thorough inspection of memory performance in the present experiments rules out this alternative explanation. Looking at participants who underwent the task with no background music, those who learned and recalled the series of geometrical figures performed above 60% at the immediate recall, while volunteers who learnt and recall the list of words recall about 40% of words in the same test. This pattern, which still appeared at long-term recall, suggests that the visuospatial memory task was equally hard, if not easier, than the verbal task. Consequently, detrimental effect of background music exclusively on memory for visuospatial material cannot be explained by higher demands of this particular task. Further experiments should experimentally manipulate the degree of intrahemispheric competition for verbal and visuospatial material by using, for instance, different background sounds, in combination with dichotic presentation designs. Additionally, subsequent research would benefit from applying these experimental manipulations within the same group of volunteers, in a repeated measures design. Furthermore, larger sample sizes have to be used to be able to detect more subtle effects of background music on memory performance. Finally, it is important to bear in mind that different types of task within the same modality (i.e., verbal or visuospatial) may not be affected by background music to the same extent. The significance of material has been shown to modulate context-dependent memory (Smith, Vela, & Williamson, 1988), so that meaningless material such as lists of non-associated words (Godden & Baddeley, 1975; Hockley, 2008; Smith & Manzano, 2010) or even full-length articles (Grant et al., 1998) may benefit more from contextual cues than meaningful information like that required to pass a college exam (Saufley et al., 1985). Thus, experiments addressing the effect of background music and hemispheric competition on the recall of previously learned meaningful materials are also needed to assess whether the effects reported here are extendable to more complex and meaningful materials.

In conclusion, these experiments suggest that part of the inconsistencies of results regarding the effect of background music on performance of simultaneous memory tasks can be explained by competition for resources in the processing of either verbal or visuospatial information. Moreover, the present results suggest that such competition might constrain any putative beneficial effects of background music for memory enhancement. Although the music context did not seem to have a successful positive effect in our experiments, some other studies have found positive effects of music in learning. Considering that competition might hinder context-dependent memory effects, future research on context-dependent memory should take into account whether the memory material and contextual cues compete for brain resources. More generally, this study highlights the importance of taking into account the material to be learned when considering using background music while learning.

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